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IN-SITU DECONTAMINATION OF METAL-POLLUTED SOILS BY METAL-ACCUMULATOR PLANTS

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Published Papers:

A. J. M. Baker, R. D. Reeves & S. P. McGrath (1991). In situdecontamination of heavy metal polluted soils using crops ofmetal-accumulating plants - a feasibility study. In: In Situ Bioreclamation: Applications and Investigations for Hydrocarbon and Contaminated Site Remediation. Ed. by R.E. Hinchee & R.F. Olfenbuttel, pp. 600-605, Butterworth- Heinemann, Boston & London.

S. P. McGrath, C. M. D. Sidoli, A. J. M. Baker & R. D. Reeves (1993). The potential for the use of metal-accumulating plants for the in situ decontamination of metal-polluted soils. In: Integrated Soil and Sediment Research: a Basis for Proper Protection, [Proceedings of the European Conference on Integrated Research for Soil and Sediment Protection and Remediation, (EUROSOL), MECC Maastricht, The Netherlands, 6-12 September 1992] Ed. by H. J. P. Eijsackers & T. Hamers, pp. 673-676, Kluwer Academic Publishers, Dordrecht.

A. J. M. Baker, S. P. McGrath, C. M. D. Sidoli & R. D. Reeves (1993). The possibility of in situ heavy metal decontamination of polluted soils using crops of metal-accumulating plants. Resources, Conservation and Recycling (in press).

Conference Papers, Abstracts, etc.:

A. J. M. Baker, R. D. Reeves & S. P. McGrath (1989). Plant accumulators of nickel and zinc - ecological curiosities or potential decontaminators of metal-polluted soils? Abstract. Paper delivered to the 7th European Meeting of the Society for Environmental Geochemistry and Health, Royal Holloway and Bedford New College, Egham, 11-14 April 1989.

A. J. M. Baker, R. D. Reeves & S. P. McGrath (1990). The potential for use of metal-accumulating plants in the decontamination of soils polluted by heavy metals. In: Abstracts of the International Conference on Metals in Soils, Waters, Plants and Animals, Orlando, Florida, USA, 30 April-3 May 1990. Abstract 188, Savannah River Ecology Laboratory, University of Georgia, USA.

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American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America, 29 October- 1 November 1991, Denver, Colorado, USA.

A. J. M. Baker, S. P. McGrath, C. Sidoli & R. D. Reeves (1992). The potential for the use of metal-accumulating plants for the in situ decontamination of metal-polluted soils. Extended Abstract. In: Preprints of the International Symposium on Soil Decontamination Using Biological Processes, Karlsruhe, 6-9 December 1992, pp. 205- 209. Dechema, Frankfurt am Main.

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A. J. M. Baker, S. P. McGrath & R. D. Reeves (1993). In situ phytoremediation of metal-contaminated soils: potentials and future prospects. Paper delivered to the International Conference of the Society for Environmental Geochemistry and Health, New Orleans, USA, 25-27July 1993. Abstracts, p. 9.

S. P. McGrath, C. M. D. Sidoli, A. J. M. Baker & R. D. Reeves (1993). Plants clean up soils. Abstract. Paper presented to the British Association Meeting, University of Keele, Staffs., UK, 30 August 1993.

A. J. M. Baker, S. P. McGrath & R. D. Reeves (1993). In situ bioremediation of metal-contaminated soils using crops of hyperaccumulator plants: potentials and future prospects for a developing technology. In: Abstracts of the Second International Conference on the Biogeochemistry of Trace Elements, Taipei, Taiwan, Republic of China, 5-10 September 1993. Abstract 55, p. 28.

A. J. M. Baker, S. P. McGrath & R. D. Reeves (1993). In situ bioremediation of metal-contaminated soils using crops of hyperaccumulator plants: potentials and future prospects for a developing technology. In: Agricultural and Environmental Biotechnology: Biodiagnosis, Biocontrols, Bioprocesses. Abstracts of the International Conference, 15-17 September 1993, Torino, Italy. p. 168. Edizione MAF Servizi, Torino.

TV Interviews (SP McGrath)

16 August 1993	BBC South East, Look East (at Woburn Plots)
15 September 1993	British Satellite News (Rothamsted Greenhouses)
11 October 1993	Anglia TV (at Woburn Experimental Plots and Rothamsted Laboratories)

Radio Interviews (SP McGrath)

9 August 1992	BBC World Service, Science in Action
28 August 1992	BBC World Service, Global Concerns
23 July 1993	BBC Greater London Radio, interview
10 August 1993	German Radio
29 August 1993	BBC World Service
30 August 1993	Radio Stoke, Country Programme
20 September 1993	BBC Radio 2, John Dunn Show

In the pipeline:

1993	BBC TV, 'Tomorrow's World'

Cabbages provide a green solution to cleaning metals out of soil

WEEDS THAT THRIVE on derelict land could soon be used to clean up contaminated sites. Research has shown that some of these plants absorb 100-200 times higher levels of metals than other vegetation – a property that scientists are trying to harness as a method of purifying soils naturally.

"Despite a number of innovative clean-up techniques coming on to the market, none are satisfactory for cleaning up metal contaminants," says Dr Steve McGrath of the Institute of Arable Crops Research at Rothamsted in Hertfordshire, one of three R&D establishments funded by the Agricultural & Food Research Council. Acid washing, for example, is one way of abstracting some metals but the process acidifies and damages the soil.

Scientists say that derelict land could be sown with the seed of chosen weeds – or hyperaccumulators – which would absorb the metals as they grow. The plants draw the metal up through their roots to their leaves and can be cropped and dried before being disposed of.

"Ultimately the metals will be abstracted and recycled," says McGrath who predicts that it will be about five years before the process is in use.

Along with Dr Alan Baker of the University of Sheffield, McGrath is studying six species from the cabbage or Brassica family that absorb high levels of zinc, cadmium, nickel and lead. Field trials have shown that some of these straggly yellow and white-flowering plants will amass zinc, for example, at levels of 33 000 parts per million. That is a 1000-fold increase compared with other plants, says McGrath.

One drawback of plant purifiers is that the process can be slow. McGrath says that one experiment to clean up sewage sludge needed nine crops. "It would be possible to get two crops a year if you grew one of them under plastic greenhouses," he explains. Selecting and breeding the most efficient plant lines could speed up the process.

The Rothamsted team is working with Dr Scott Cunningham of Du Pont Chemicals in Newark, Delaware, one of the main centres of research in this area. Cunningham sees plants as a viable remedial option where pollutants are near the surface; are relatively non-leachable; pose little risk to health or the environment, and cover large areas. Like McGrath, he says that hyperaccumulators could be in widespread use in five years' time.

Cunningham points out that at some US sites, plants are already used for stabilising contaminants in the soil. Trials are also under way to use different species for cleaning up organic contaminants – such as herbicide spills. The US Army is experimenting with Bermuda grass for cleaning up oily sludges and the Department of Energy is trying to use pine trees for cleaning spills of trichloroethylene on the nuclear weapons manufacturing site in Savannah River, Georgia.

Cunningham's research group is concentrating on ragweed, another high metal accumulator which could prove especially effective because of its size - species grow up to 3 m high. Ragweed is particularly effective in absorbing lead – *ubiquitous* because of car exhaust. The group is also beginning to genetically engineer species to increase metal uptake. But before manipulating the genes, the team has to pinpoint those responsible.

"We are on the right track," says Cunningham of his research. "Plants are already being used for cleaning up indoor air contamination and waste water streams. It's a logical step to use them to clean up soil."

PHIL WARD

13/8/92

AGRARISCH DAGBLAD

Planten reinigen verontreinigde grond

JAN WARNERDAM

LONDEN – Onderzoekers van het Britse onderzoeksinstituut Rothamstead Expertimental Station (nabij Londen), zijn erin geslaagd zware metalen uit de grond te verwijderen door middel van teelt van specifieke plantensoorten.

Het Rothamstead-team verzamelde tijdens expedities naar Duitsland, België, Griekenland en Portugal zaden van planten die gedijen op grond waar van nature een hoge mate van zware metalen aanwezig is.

Meest geschikt om grond te zuiveren bleken kruisbloemige plantensoorten van de Brassica familie (waartoe ook de koolsoorten behoren). Het gaat om drie rassen Alyssum (lesbiacum, tenium, murale), een aantal species van Thlaspi, en een plant genaamd Cardaminopsis halleri.

Absorptie

De onderzoekers zaaiden de planten op een perceel in Zuid-Engeland, waarop in het verleden veel rioolslib was uitgereden. In het kleinschalige experiment wordt een hoge mate absorptie van zware metalen bereikt. Per hectare nemen de planten veertig kilo zink, 1200 gram nikkel, en 150 gram cadmium op.

"Dat is tientallen malen meer dan onttrokken wordt door normale landbouwgewassen", zegt leider van het onderzoeksteam Dr Steve McGrath. "Om een voorbeeld te noemen, een koolzaadgewas neemt driehonderd gram zink op, twintig gram nikkel, en tien gram cadmium."

Gevaarlijk

Volgens McGrath zijn zink, nikkel en cadmium de grootste boosdoeners in de teeltlaag. "Niet alleen zijn deze metalen schadelijk voor het bodembacterie-leven, maar ook voor mens en dier. Vooral cadmium is gevaarlijk. Daarvan moet niet teveel in de consumptie-keten terecht komen."

Uit eerder onderzoek is gebleken dat ook lage concentraties metalen uit slib al een negatief effect op het bodemleven hebben. De stikstofbindende bacterie Rhizobium leguminosarum biovar trifolii blijkt extreem gevoelig te zijn. Deze bacterie leeft in de wortelknobbels van klaver en bindt stikstof uit de lucht.

Uit de eerdere experimenten konden de onderzoekers niet met zekerheid concluderen welk metaal nu precies verantwoordelijk is voor de dood van de bodemorganismen.

Loodverzamelaar

Mc Grath heeft nog geen succes behaald met verhoogde opname van koper, lood en chroom. "Daar zoeken we nog plantensoorten voor", zegt hij. "We zoeken het hardst naar een forse loodverzamelaar."

Het Rothamstead-onderzoek is het enige in de wereld en direct van belang voor de praktijk. Percelen die hevig zijn aangetast door zware metalen, zouden effectief 'schoongeteeld' kunnen worden. De geoogste planten (die na de opname van zware metalen beschouwd kunnen worden als chemisch afval) kunnen onder gecontroleerde omstandigheden verbrand worden.

Dit zou een veel goedkopere manier van grondreiniging zijn dan afgraven.

"Het is de enige praktische manier om zware metalen uit de teeltlaag te verwijderen", zegt McGrath. Het onderzoek spitst zich toe op een ideale combinatie van planten voor specifieke doeleinden, zogezegd een cocktail van plantensoorten gericht op de metalen die in een bepaald perceel problemen opleveren.

Zaadpakkettem

McGrath verwacht dat, wanneer het onderzoek verder is gevorderd, samengewerkt zal worden met een commercieel bedrijf, zodat zaadpakkettem op de markt kunnen gebracht. "We zijn in ieder geval al zover dat we de zaadlijsten rioolslib-metalen uit de grond kunnen krijgen; een vervuild perceel kan binnen drie tot vijf jaar redelijk schoongemaakt worden, dat hebben we reeds experimenteel bewezen", aldus McGrath.

"Ons onderzoek is van internationaal belang, we werken samen met Sheffield Universiteit, en Massey Universiteit in Nieuw Zeeland." Het huidige onderzoek wordt door de EG gefinancierd.

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TV Interviews (AJM Paker)

May 1992	Calendar News, Yorkshire Television [Gang Mines, Derbys; Labs. University]
25 June 1993	Newsround, BBC TV [Gang Mines, Derbys]

Films

15 July 1993	Film Unit, Central Office of Information [Gang Mines, Derbys; Labs. University]

Radio Interviews/Programmes

18 May 1993	Radio Sheffield, live
19 May 1993	LBC Newstalk, 18.45, live
19 May 1993	LBC 20.45, live
4 & 6 June 1993	BBC Radio 4, Natural History Programme
7 June 1993	BBC Radio 4, 'You and Yours'

In the pipeline:

1993	BBC TV, 'Tomorrow's World'
1993/94	Transatlantic Films. Filming over next two years for 'Plant Hunters' series on Discovery Channel

Remediation technologies

Various strategies exist worldwide, although in the UK remediation technology is a very young industry. Barry Ellis of Celtic Tehnologies has outlined some basic approaches:

- containment — synthetic liners, modified clay liners, jet grouting, slurry walls, ground freezing
- reduction of contaminant mobility — stabilisation and solidification
- contaminant removal — vacuum extraction, air stripping
- biological destruction — land spreading, composting and treatment bed destruction
- physical removal in situ — soil flushing
- physical removal ex situ — soil washing
- physical removal on-site — pump and treat
- high temperature oxidisation — thermal processing

It has to be remembered that remediation technologies are developing all the time and as the market grows the cost of remediation could fall. Rothamsted Experimental Station (part of the Agricultural and Food Research Council) is developing a low tech solution based on plants absorbing heavy metals within one metre of the topsoil. Scientists have had success with plants from the cabbage family

Plants of *Alyssum*, *Thlaspi* and *Cardaminopsis* growing in a plot of a metal contaminated field at Woburn in Bedfordshire. These are field tests of the efficiency of these hyper-accumulator plants at removing heavy metals in the above-ground material, which can then be cut, taken away and recycled

Picture courtesy of Rothamsted

Premises & Facilities Management

BBC WORLD SERVICE

SCIENCE IN ACTION

AUGUST 9, 1992

11.00

PRESENTER:

The world's first experiment to see if plants could decontaminate polluted land is now under way in Britain. A team at the Rothampstead Agricultural Research Station at Harpendon near London have succeeded in developing plants which will grow in soil heavily contaminated with toxic heavy metals.

And not only will the plants grow in such soils, they absorb the metals from the soil into their stems and leaves. Then the plants can be harvested and heavy metals -, which are extremely valuable in industry, although they are toxic in the environment - can be recycled back into industrial uses.

Team leader Dr Steve McGrath says he believes that the plants he's developed - which are known as hyper-accumulators because they can absorb hundreds of times more metal than normal - are going to provide a safe, natural and cost-effective way of cleaning up contaminated soils.

END

The Hindu.
September 1992

Decontaminating soil by plants

The world's first field experiment to test the potential of special plants to decontaminate polluted land is now under way in the U.K.

A team of scientists at the U.K. Agricultural and Food Research Council's (AFRC) Rothamsted Experimental Station at Harpenden, near London, has succeeded in developing plants that can grow in soil highly contaminated with heavy metals. Their experiments indicate that the plants can absorb the heavy metals from the soil, eventually leading to decontamination. It is likely that this research will lead to a safe, natural and cost-effective method for dealing with the problem of soil contamination.

Heavy metals such as zinc, cadmium and copper, which are present in sewage sludge, can have disastrous effects on the soil microbial population in treated farmland.

Over the past few years it has been found that even small concentrations of metals from sewage sludge applied to agricultural land can seriously interfere with soil microbiological activity. Rhizobium *leguminosarum biovar trifolii*, the nitrogen-fixing bacterium that infects clover roots, is particularly sensitive.

In experimental plots of land contaminated with metal, only one strain of soil bug was tolerant to metals but unable to fix nitrogen with the normal host. Scientists involved in these experiments found it impossible to establish which of several different metals was responsible for the death of effective strains of microbe.

In the latest experiments, increasing concentrations of zinc, cadmium, copper and nickel were added separately to soil from the uncontaminated control plot of the experiment. The results showed that adding zinc at 1.3 times the U.K. limit for this element in sludge-treated soil, or cadmium at 2.4 times the limit, caused complete death of effective strains of microbe within 18 months. Copper at 1.7 times the limit decreased the number of deaths but did not cause complete elimination, and nickel had no effect.

Most plants at best can only remove small quantities of toxic metals from soil. But the present work has given new hope because the team has found that some specialised plants, known as hyper-accumulators, can absorb much larger concentrations of metals.

It has been shown that hyper-accumulators can absorb 10,000 mg zinc for every one-tenth of a kilogramme of dry matter, compared to about 30 mg in normal plants. In the case of cadmium, they can absorb 100 mg per one-tenth of a kilogramme of soil compared with the usual one milligramme. — LPS

University study finds plants absorb heavy metals

Wild cabbages 'cure for polluted land'

Richard Sadler
Environment
Correspondent

RESEARCHERS at Sheffield University are pioneering a simple and harmless technique for cleaning up contaminated land — by covering the ground with wild cabbage plants.

A research team headed by Dr Alan Baker, a senior lecturer in the university's department of animal and plant sciences, has just completed a two-year trial testing the capacity of selected wild plants to absorb poisonous heavy metals such as zinc, cadmium, nickel and chromium.

The project, carried out jointly with scientists at the Agriculture and Food Research Council's Rothamsted experimental station at Harpenden, Herts, has shown that plants can be more effective in stripping contaminants from topsoil than expensive and environmentally-destructive methods now being used.

As an added bonus the metals absorbed by the plants can be recycled.

Thousands of acres of industrial land throughout Britain — as well as some arable farmland — are polluted by heavy metals from industrial and municipal waste dumping, metal smelting and contaminated sewage sludge used as a fertiliser.

Publicity over Government plans to make landowners liable for past contamination has played a blight on many derelict industrial areas, including the Wath and Dearne Valleys in South Yorkshire.

The only attempts to clean up soils contaminated by heavy metals have been in the United States, using processes where the soil is steeped in acid or saturated with glass particles.

Both these techniques are expensive and they leave behind a sterile soil which takes at least a decade to recover.

The Sheffield-Rothamsted project, funded jointly by the EC and the US chemicals multi-national firm, Du Pont, has involved experiments with several obscure species of wild cabbage from Britain, Belgium and Greece.

Dr Baker said: "I have been working for [illegible] the evolution of resistance to materials in plants and a number of plants have shown unusual behaviour where as part of their tolerance to certain toxic materials, they actually absorb them.

"It has emerged that quite a range of plants accumulate these materials in their tissues and shoots and we have realised there may be a way of using them to clean contaminated soil biologically rather than chemically.

"We now have proof of the concept — what we now need is a massive development programme to breed the most promising species in later numbers so this technology can be implemented on a practical scale."

Guardian 18 May 1993

'Metal detecting' wild cabbages set to clean up poisoned land

Martin Wainwright

WILD cabbages may soon be deployed to mop up Britain's abandoned industrial sites, after the success of an investigation into their powers of absorbing toxic sludge.

Scientists from Sheffield University and the Government's Rothamsted experimental laboratories have found the plants can be more effective at neutralising metallic poisons than current detoxifying techniques.

The successful trials are likely to see the pale yellow blooms of wild cabbage join purple buddleia and pink willow herb as a part of the inner city landscape.

There are also hopes that "cabbage-cleaning" could speed the renaissance of abandoned sites, in areas from London to South Yorkshire, where developers have been deterred by problems with cadmium, zinc or nickel traces.

The cabbage trials, funded by the European Community and Du Pont, the US chemical firm, have used a range of relatively uncommon species from Britain, Belgium and Greece. Dr Alan Baker, a senior lecturer in Sheffield's animal and plant sciences department, said the two-year experiment had proved a theory developed over 30 years' study.

Wild cabbages, which include brassicas like the favourite rockery plant alyssum, have developed an ability to adapt to poisons in the soil by absorbing them harmlessly into shoots and tissues. Their appetite appears to extend beyond metals to municipal rubbish and contaminated sewage sludge.

Dr Baker said yesterday: "A very small number of species go further and actively seek out toxins to take up, possibly as a defence mechanism against predators." These vegetable metal-detectors will be at the centre of the project's next stage.

The research team is now hoping to breed the most voracious strains in large numbers, to tackle sites currently abandoned or treated slowly and expensively by acid-dousing or saturation with glass particles.

The Star
BUSINESS
THE WORLD OF WORK AND MONEY
Wednesday, May 19, 1993

INSIDE
Seals of quality P4 & 5

Pollution eaters

Sheffield scientist in research on how plants could clean contaminated sites

Alan Baker: green target

PLANT power could soon be cleaning up derelict land, thanks to research involving Sheffield University scientist Alan Baker.

Dr Baker, an expert on how metals in the soil affect plants, has been using his knowledge as part of a pollution-busting European Community-funded research project.

Now American chemicals giants Du Pont are showing interest in backing further research aimed at increasing the speed at which the plants absorb metals like zinc, lead, cadmium, nickel, copper and cobalt from the soil.

Tests involving a range of wild and sometimes rare plants which thrive on soils with high metal concentrations that would kill other species proved that they could be used to clean up plots of land over a period of years.

By Robert Rae
Industrial Editor

The plants concentrate the metals in their shoots, which are harvested and burnt. The ash — which can contain between ten and 20 per cent metal — is either recycled or disposed of as a hazardous waste.

The Star Says: P6

Dr Baker has been working with Dr Steve McGrath, of the Institute of Arable Crops Research, who reckons it could be up to five years before plant power is being used to provide a green solution to pollution problems.

Even then, stresses Dr Baker, plants will not be a commercially viable solution when it comes to cleaning up heavily polluted sites or sites where the pollution is well below the surface soil.

"This is not a technique that is viable for rapid clean-ups but it is an option for marginal land which is slightly contaminated and not wanted immediately for redevelopment," says Dr Baker, whose work is featured in the latest edition of the magazine Building.

Many of the plants being used come from Europe, but some are from Africa where they are found at high altitudes on land with naturally occuring metal deposits.

Some of the European species are so rare that they are officially protected but, if Dr Baker's research pays off, they could be a lot less rare in the future.

Plants being used include straggly yellow and white-flowering plants from the cabbage family that absorb zinc and ragweed, which is particularly good at absorbing lead.

Bakery boost

Extract from
Wolverhampton Express & Star

21 May 1993

Weeds provide green solution to cleaning soil

By Denise Chevin

WEEDS AND other plants could soon be used to clean up land that has been left derelict because the soil is contaminated with high levels of metals, according to a report in the current issue of the magazine Building.

At present there is no satisfactory way of cleansing soil of metal contaminants without damaging the soil. However, research has shown that some plants absorb 100 to 200 times higher levels of metals than other vegetation, and scientists are trying to harness this ability as a method of purifying soils naturally.

They believe that derelict land could be sown with the seed of chosen weeds – or hyperaccumulators – which would absorb the metals as they grow. The plants draw the metal up through their roots to their leaves and can be cropped and dried before being disposed of.

Dr Steve McGrath of the Institute of Arable Crops Research at Rothamsted in Hertfordshire, one of the three research and development establishments funded by the Agricultural Food and Research Council, says that ultimately the metals could be abstracted and recycled and predicts that it will be about five years before the process is in use.

Along with Dr Alan Baker of the University of Sheffield, McGrath is studying six species from the cabbage or Brassica family that absorb high levels of zinc, cadmium, nickel and lead.

Field trials have shown that some of these straggly yellow and white-flowering plants will amass zinc, for example, at levels of 33,000 parts per million. That is a 1,000-fold increase compared with other plants, says McGrath.

One drawback of plant purifiers is that the process can be slow. McGrath says that one experiment to clean up sewage sludge needed nine crops.

"It would be possible to get two crops a year if you grew one of them under plastic greenhouses," he said. Selecting and breeding the most efficient plant lines could speed up the process.

The Rothamstead team is working with Dr Scott Cunningham of Du Pont Chemicals in Newark, Delaware, one of the main centres of research in this area. Cunningham sees plants as a viable remedial option where pollutants are near the surface, pose little risk to health or the environment and cover large areas.

He points out that at some US sites, plants are already used for stabilising contaminants in the soil. Trials are also under way to use different species for cleaning up organic contaminants, such as herbicide spills.

The US Army is experimenting with Bermuda grass for cleaning up oily sludges and the Department of Energy is trying to use pine trees for cleaning spills of trychlorosethylene on the nuclear weapons manufacturing site in Savannah River, Georgia.

Cunningham's research group is concentrating on ragweed, another high metal accumulator which could prove especially effective because of its size – species grow up to three metres high. Ragweed is particularly effective in absorbing lead.

The group is also beginning to genetically engineer species to increase metal uptake. But before manipulating the genes, the team has to pinpoint those responsible.

"We are on the right track," says Cunningham. "Plants are already being used for cleaning up indoor air contamination and waste water streams. It is a logical step to use them to clean up soil."

Tasty toxins tempt green gourmets ...

Plants will be genetically engineered to clean up the toxic compounds which contaminate large areas of soil in industrial countries.

This is the aim of research projects being carried out and supported by DuPont.

'Metal-eating' plants derived from rare wild relatives of common or garden plants, such as cabbage, cress, turnip and ragweed, will remove pollutants from and restore them to productive use.

In DuPont's central research and development division at Glasgow, Newark, USA, Dr Scott Cunningham and his colleagues are two years into a programme looking particularly at lead-contaminated soils.

At Sheffield University's animal and plant sciences department in England, Dr Alan Baker's search for plants which have evolved a natural resistance to metals is funded by DuPont. Dr Baker has been studying metal resistance in plants for more than 20 years.

'Some plants actively bio-accumulate metals and detoxify them internally,' he said.

'A considerable percentage of the plant's weight can be made of metal. Some of the zinc-accumulating plants are virtually galvanised.'

The brassica family, which includes the wild cabbage, radish, shepherd's purse, cress, oil seed rape and turnip, are particularly adept at metal accumulation. It is not the familiar strains which are creating interest, however, but relatively rare adaptations only found in areas where metals occur naturally in the earth.

Dr Baker has travelled the world in pursuit of these plants known as 'hyperaccumulators'.

He found a tree in New Caledonia, for example, which had accumulated so much nickel – up to 25 per cent of the plant's latex – that if the bark is cut it bleeds blue sap.

Dr Baker built up a seed bank of green metal detecters and tested them on an ideal site at Woburn in the UK, inadvertently created by an experimental crop growing project which ended 30 years ago.

Unknown to those experimenters at the time, the treated sludge they spread annually and ploughed into the soil for 20 years was contaminated.

The soil, when Dr Baker came to use it, was a perfect metal cocktail for testing nine promising accumulator species.

'Most of the plants are perennials, including relatives of the popular garden plant alyssum exclusively found on a few Greek islands,' said Dr Baker. Accumulator plants are normally best at dealing with one specific metal, although most also take up other metals to a lesser degree.

'We are looking towards genetically engineering a model plant which will be able to deal with more than one metal,' added Dr Baker.

'Such a plant could have the potential to clean up a site within six to eight years.'

Dr Cunningham's work for DuPont concentrates on lead because the company is committed to cleaning up sites contaminated many years ago when they produced lead-based products and explosives. Scott has been investigating many old former DuPont sites, as well as land where lead lined buildings had been burnt and even old smelter sites dating from the American Revolutionary and Civil Wars.

'Of the plants we have analysed to date, two have shown significant abilities to accumulate lead: hemp dogbane and common ragweed,' he said.

'Their lead accumulation abilities are not consistent in every soil. Most metals – and lead in particular – have numerous forms, not all of which are equally available for plant uptake.

'Our ultimate aim is to clone genes into the plants.'

The stakes are high: in the US alone the estimated cost of cleaning up hazardous waste is $752 billion over the next 30 years. Other parts of the world have similar problems and there is even hope of developing plants which could clean up the radioactive debris of the Chernobyl nuclear disaster.

It has even been suggested that bio-mining could get rid of conventional mining completely by planting metal-bearing crops, harvesting them, and smelting them to recover the metal.

'The potential uses of plants which absorb toxins are numerous,' says Scott, who is about to start work with Conoco in Ponca City to look at plants which might clean up oily sludge. A species of Bermuda grass is already known to grow on and help clean up oily sludge.

It is early days yet but hopes are high that current research will eventually allow scientists to send in the clones and make the solution to the major problem of contaminated industrial land a truly green one.

... while busy bacteria help clean-up our act

A DuPont team has developed technology that uses natural soil bacteria to clean up groundwater and soil contaminated with chlorinated hydrocarbons, solving a major environmental and public health challenge.

Chlorinated solvents, also known as chlorinated hydrocarbons, are one of the most common pollutants in groundwater worldwide.

They are often by-products of manufacturing operations and are used in dry-cleaning fluids, metal finishing and electronic circuit fluids.

For the first time, bioremediation has removed chlorinated hydrocarbons thoroughly enough to meet the stringent Environmental Protection Agency's drinking water standards.

The technology involves establishing an anaerobic – oxygen-free – environment in which naturally occurring bacteria use the contaminants as an oxygen substitute.

Anaerobic bioremediation is faster and more cost-effective than other methods, such as the commonly used 'pump and treat' technology.

It has previously been used successfully to treat gasoline and petrol but never with chlorinated hydrocarbons, which are extremely hard to break down.

The team, which includes Conoco and DuPont representatives, demonstrated the technology at DuPont's Victoria, Texas site and is now testing the method to determine how broadly this technology can be applied.

In another development, a fourth 'R' has been added to DuPont's waste reduction arsenal.

Reduce, Reuse and Recycle have been joined by 'Rot', with bacteria and other micro-organisms being enlisted to help make sure that an important new DuPont plant meets environmental targets.

In DuPont's first large scale waste composting operation, the natural process of plant decay will not only help to treat wastes at the adipic acid plant in Singapore, but create a product beneficial to the environment.

When the plant starts up in 1994, organic wastes from the manufacturing process will be fed to bacteria and other micro-organisms.

As these organisms feed, grow and multiply, they'll be periodically removed and mixed with wood chips to form compost.

'We'll speed up the natural composting process by providing optimal growing conditions, namely air and water at the right temperatures,' explained Deb Luper of Engineering's Water and Waste Management Group.

Initially, the plan was to burn the excess microbes from the waste water treatment process. It is estimated that composting will cost several million dollars less than incineration, while creating a beneficial product.

Once the safety of this is verified by DuPont, independent researchers and government agencies, it will be used to decrease erosion and promote lush vegetation at the sandy Singapore site, and marketed in neighbouring countries.

In Univ. Sheffield Newsletter 9 June 1993 p8.

'Green' solutions to heavy metal pollution

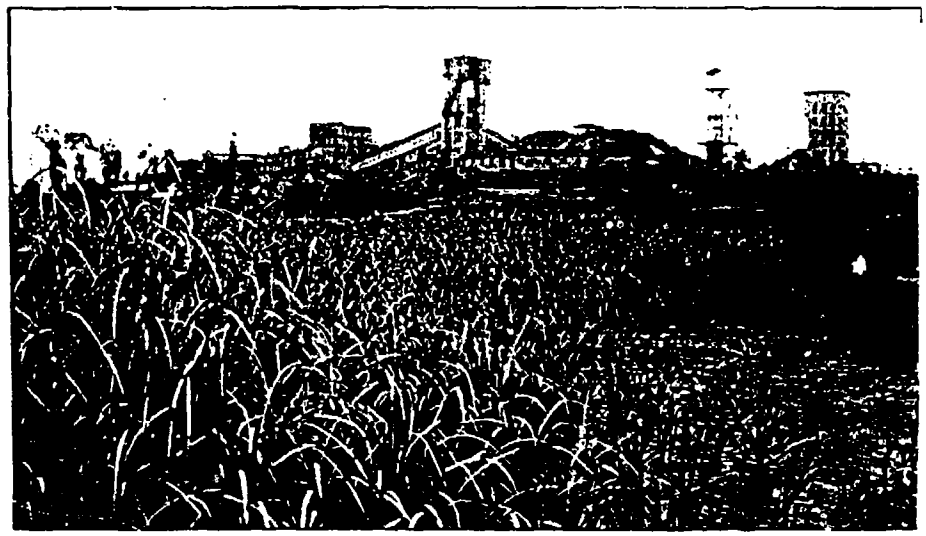
Baker. A. J. M.

Wild relatives of the cabbage could soon be used to help clean up Britain's contaminated industrial sites, following the success of a two-year trial conducted by a research team headed by Dr Alan Baker in the Department of Animal and Plant Sciences.

The project, carried out in collaboration with Dr Steve McGrath (a former BSc and PhD graduate of this University) at the Agriculture and Food Research Council's Rothamsted Experimental Station in Hertfordshire, has demonstrated that certain plants can be effective in removing potentially toxic heavy metals such as zinc, cadmium, lead and nickel from polluted land.

The 'green remediation' process they are developing could ultimately prove a less costly alternative to physico-chemical clean-up techniques currently employed in the USA and the Netherlands. It would also have the advantage of retaining the biological integrity of the soil rather than producing a sterile growth medium which generally results from present treatment options.

Funded by the EC and the American chemical firm DuPont, the plant trials have used a range of relatively uncommon metal-accumulating species from the UK, Belgium and Greece. These unusual plants, with a capacity to bioaccumulate several percent of metals in their shoots, have been identified by Dr Baker during research over the last twenty years. Whilst in the cabbage family, the nearest domesticated relatives of the plants being tested are the cresses and the common rockery plant, alyssum. All are native to soils naturally rich in heavy metals, often in areas of major mining operations.



A settling pond receiving effluents from China's second largest zinc mine at Shaoguan, Guangdong Province, has been planted with dense stands of the reedmace Typha latifolia *to remove contaminant heavy metals from the effluent waters and then immobilise them in sediments.*

Fundamental aspects of the mechanisms of metal accumulation by such plants are currently being investigated by Dr Baker and his research group. Some of the plants can scavenge metals from low soil concentrations, actively accumulating them in their shoots to similar concentrations as those found in plants growing naturally on the most metal-enriched soils. Dr Baker's group are investigating the possible role that the accumulated metals may play as a deterrent to herbivory and in control of pathogens.

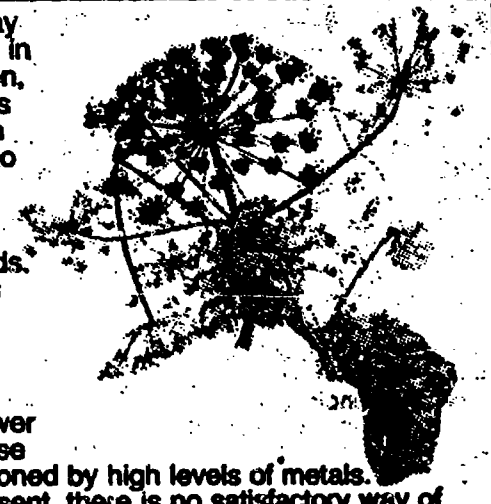
Commenting on the project, Dr Baker said: "We have proof of concept - what we now need is a major development programme to breed and improve the most promising species and to generate sufficient materials so that this technology can be tested on a practical scale."

Another 'green technology' project underway in the Department of Animal and Plant Sciences involves the use of fast-growing, productive wetland plants - like the reedmace and common reed - to clean metal-polluted effluents from mining and mineral processing works.

Dr Baker and a research student, Mr Zhihong Ye, are collaborating with research groups at Baptist College, Hong Kong, and Zhongshan University, Guangzhou, PR China, in a project on the r of wetland plants in metal immobilization i both natural and constructed wetlands. The study, using materials from both Europe an China, aims to elucidate the mechanisms involved, and to allow selection of particularly useful strains of wetland plants for further development.

Liverpool Echo, Tuesday, June 29, 1993

Weeding out the baddies



THEY may be a pest in the garden, but weeds may soon be used to clean up our dark industrial wastelands. Scientists in Britain are now trying to harness weed-power to revitalise land poisoned by high levels of metals.

At present, there is no satisfactory way of getting rid of the metals without damaging the soil.

However, research has shown that some weeds absorb 100 to 200 times higher levels of metals than other vegetation.

And it is believed that they could be harnessed to ensure a natural way of cleaning up the soil for good — by absorbing the metals as they grow.

Harvested, they could then be cut up, dried and disposed of safely.

Dr Steve McGrath of the Institute of Arable Crops Research in Hertfordshire says that the ultimate aim is to remove the metals from the weeds and recyle it.

And he predicts that it will be only five years before the process is in use.

However, the actual clean-up could be a slow process: one experiment with sewage sludge needed nine crops of weed.

But says Dr. McGrath: "It would be possible to get two crops a year if you grew one of them under plastic greenhouses."

And selecting and breeding the most efficient plant lines could speed up the process.

DENISE CHEVIN

July 1993

WASTES MANAGEMENT
-Northampton-

Wild cabbage and contamination

Wild cabbages may be used to clean up abandoned industrial sites following an investigation into their ability to absorb toxic waste, according to a recent report in The Guardian.

Scientists from Sheffield University and the Government's Rothamsted experimental laboratories have found the cabbages can be even more effective at neutralising metallic poisons than current detoxifying techniques.

The trials have been funded by US chemical company Du Pont and the EC.

Earth Almanac

BAKER/MOORE, KATZ PICTURES

The Future Is Now for a Global-warming Test

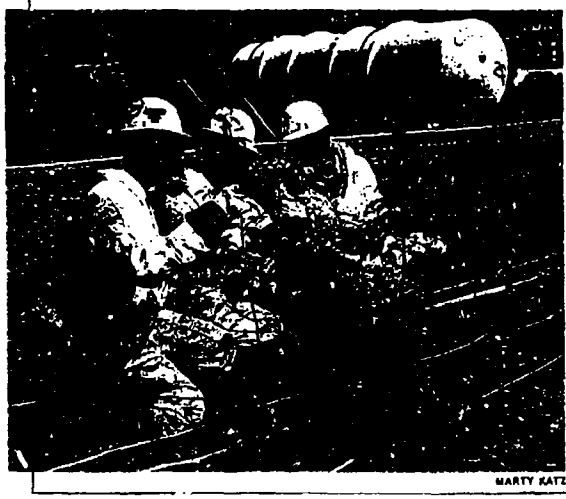
How will plants adapt to the greenhouse effect—rising temperatures and carbon dioxide levels, the wages of fossil fuel burning and deforestation? To study the effects of such climate change, British scientists quite sensibly are using greenhouses—eight very sophisticated greenhouses (colored by creative photography) called Solardomes.

Built on the coast of Wales by the Institute of Terrestrial Ecology, the domes create conditions predicted for the late 21st century. Their air contains twice today's carbon dioxide and is 5.4°F warmer than outside air. Growing in the domes, grasses and small oaks and sycamores are measured by scientists, who also monitor caterpillars and aphids that feed on the vegetation. "Some plants may adapt by growing quicker and bigger. Others may slow down," says project leader Trevor Ashenden.

Contaminated Soil: Can Plants Get the Lead Out?

For 30 years an E. I. du Pont de Nemours & Co. plant in Deepwater, New Jersey, made tetraethyl lead, a gasoline additive that was phased out in the 1980s. High concentrations of lead now contaminate 25 acres. Yet in this wasteland, two weeds—common ragweed and hemp dogbane—not only grow but thrive, even as lead accumulates in their tissues. So company researchers (left, from left to right) Scott Cunningham, Steve Germani, and Bill Berti have planted more of the weeds to see if these and other plants can draw significant amounts of heavy metals from contaminated soils, a technique called plant remediation.

"All plants store some metals in their roots," says Scott, "but a few have likely gained an advantage by storing them in their leaves too. That way they may avoid being eaten by bugs or infected by a fungus." If the researchers can increase a weed's lead intake to one percent of its mass, the plants could be cut, dried, and burned to reclaim and recycle the lead.



MARTY KATZ

Tiny Desert Fox Must Be Wily to Survive

Life presents a host of hazards for the cat-size San Joaquin kit fox. Of this endangered subspecies only about 5,000 remain. Their southern California neighbors include coyotes and golden eagles, which prey on them. A bullying outsider, the red fox, is invading their territory. Agriculture has gobbled up more than 90 percent of the kit foxes' former range, virtually restricting them to the Carrizo Plain, a 400-square-mile basin of grassland and scrub. And that shrunken habitat can be seared by drought.

VULPES MACROTIS MUTICA, B. "MOOSE" PETERSON

But the foxes have friends. The Nature Conservancy has bought a 23,000-acre ranch, expanding the Carrizo Plain Natural Area to 200,000 acres, which the group manages in cooperation with the state and the U. S. Bureau of Land Management.

—JOHN L. ELIOT

Flower power rocks heavy metal

Paul Lewis talks to two of the scientists who are harnessing nature's power to clean up polluted sites.

SOME of Britain's ugliest and most polluted sites could soon be transformed into fields of brilliant yellow and white flowers as a result of a new, low-tech way of reclaiming contaminated land.

More importantly, the beautification would not just be visual. It would cleanse the soils of toxic heavy metals such as zinc, cadmium and nickel, and could be the first step in harnessing nature to fight back against pollution.

It is all down to the ability of certain unremarkable plants, including cresses and other members of the cabbage family, to flourish on poisoned soils and absorb metallic toxins through their roots.

The metals were deposited by industrial effluent, sewage sludge and airborne pollution and have made thousands of acres across the country dangerous and unusable.

Reclaiming the land used to cost huge sums and kill off any life it contained. The two favoured methods were acid leaching to dissolve out the metals, and baking at more than 1,000C to fuse them with the silica in the soil.

Successful trials of plant 'hyperaccumulators' at Sheffield University's department of animal and plant sciences should soon render such extreme measures obsolete. Scientists have been growing pennycress and similar crops on a site near Woburn which was poisoned by 20 annual applications of sewage sludge.

Dr Alan Baker, a senior lecturer at the university, says the results could herald the beginnings of a natural revolution in clean-up technology.

He and Professor Steve McGrath at Rothamsted's Institute of Arable Crops Research found plants from the cress and *alyssum* families growing naturally on metalliferous soils in Britain and on the Continent and decided to try them on the contaminated site at the research centre.

'We grew our plants on site and then uprooted them, and planted them so they were pitted against the soil. What we found was that some were highly successful at accumulating metals such as zinc and nickel. Until now, metals like these have been the most intractable of all environmental pollutants,' Baker said.

'This could be at least a start to decontamination that doesn't remove all biological activity from the soil. It could be a first step in using a truly green approach to turn the tide against pollution.'

The cresses would at first be used on sites that have only been 'marginally polluted' and would be a cheap, visually pleasing way of reclaiming land for housing, parks or industry.

The current high costs of acid leaching or baking soil means that so far only prime sites such as those in the centre of London have been worth cleaning. All that is set to change.

So effective are the cresses that, once cleaned, land could safely be returned to agricultural and horticultural uses. Together with other techniques, the processes may even be used to decontaminate more severely polluted sites.

Though one of the species of cress involved is native to Britain, Baker is refusing to name it, or say where it grows. His concern is that an already rare plant could become a target for collectors.

In other countries hyperaccumulator species are under threat as rainforests are cleared and Baker believes there is an urgent need to collect the plants and cultivate them for their own protection. Once over that hurdle, large-scale use for soil cleansing can start.

The technology could have other far-reaching applications. One could be as a way to recycle metals lost as industrial or other waste. When the cresses are harvested and incinerated, the ash contains up to 20 per cent metal oxides from which it is easy to remove the metals.

Though this is unlikely to be commercially viable yet, it may well become so as reserves are depleted and genetic engineering increases plants' ability to absorb the metals.

Another enticing prospect is that there may be 'hyperaccumulator' plants for other metals. A huge range of flora has not even been classified, let alone investigated for potential exploitation.

McGrath has high hopes for this: 'New hyperaccumulators are being found all the time. We already know of 243 for nickel alone. We have expeditions to the tropics every year and they usually return with information on two or three new accumulators.

'We know of a chromium accumulator growing in tropical regions, but this would obviously not be suitable to the climate in this country. We're also investigating the lead-accumulating properties of another plant, though it's too early to be sure yet,' he said.

Baker believes it is possible that accumulators may be found for precious metals, a prospect which could make him extremely rich.

His work, it seems, brings the dream of harvesting fields of gold and silver one step closer to reality.

Natural cure: The Alpine pennycress, which absorbs heavy metals./Photograph by David Manuell.

The Observer, 1st August 1993

Marler Zeitung
Nr. 198 / Donnerstag, 26. August 1993
"Aus aller Welt"

Metallfressende Pflanzen entgiften Böden

„Hyperakkumulatoren" nehmen große Mengen an Schwermetallen auf / Rückgewinnung

LONDON. (dpa) Metallfressende Pflanzen gedeihen auf einem Feld des Institutes für Ackerbau und Getreidekunde in Rothamsted bei London.

„Hyperakkumulatoren" hat sie der Biologie-Professor Steve McGrath wegen ihrer metallspeichernden Eigenschaften getauft. Hunderte von Sorten gibt es, unter ihnen das Alpine Pfennigkraut und verschiedene Kohlarten. Nicht in Promille, sondern in Prozenten ihres Eigengewichtes ziehen sie Schwermetalle aus dem Boden und speichern sie, so McGrath. Er hofft, daß sich nach der Ernte aus der Pflanzenasche, die zu 20 Prozent aus Metalloxiden besteht, Metalle wiedergewinnen lassen.

Erste Versuchsergebnisse stimmen ihn „sehr, sehr optimistisch": Schon nach zehn Ernten habe sich der Anteil an Schwermetallen in einer Industriebrache auf landwirtschaftlich akzeptable Werte gesenkt. Der Boden war mit Kupfer, Cadmium, Nickel, Chrom und Blei verseucht gewesen. Eine besondere Vorliebe haben die Pflänzchen für Cadmium und Zink entwickelt.

Scientists using flowers to suck toxics out of ground

By Paul Lewis
London Observer

LONDON – Some of Britain's ugliest and most polluted sites could soon be transformed into fields of brilliant yellow and white flowers as a result of a new, low-tech way of reclaiming contaminated land.

More important, the beautification would not just be visual; it would cleanse the soils of toxic heavy metals such as zinc, cadmium and nickel and could be the first step in harnessing nature to fight pollution.

The plan hinges on the ability of certain unremarkable plants, including members of the cress and cabbage families, to flourish on poisoned soils and absorb metallic toxics through their roots.

Thousands of acres across Britain have become dangerous and unusable as a result of industrial effluent depositing, sewage sludge and airborne pollution. Reclaiming such land usually costs huge sums and kills any life on the land. The two favored methods were acid leaching to dissolve out the metals, and baking at high temperatures to fuse them with the silica in the soil.

But success with plant "hyper-accumulators" at Sheffield University may soon render such measures obsolete.

> "It could be a first step in using a truly green approach to turn the tide against pollution."
> – scientist Alan Baker

Scientists have been growing pennycress and similar crops on a site near Woburn polluted by sewage sludge.

Alan Baker, a senior lecturer at the university, said the results could herald the beginning of a natural revolution in cleanup technology. Baker and Professor Steve McGrath at the Institute of Arable Crops Research search found plants from the and alyssum families grow naturally on metalliferous soils in Britain and in Europe and ed to try them on the contam ed site at the research center.

"What we found was that were highly successful at accum lating metals such as zinc and nickel. Until now, metals like these have been the most intractable of all environmental pollutants," Baker said.

"This could be at least a start to decontamination that doesn't remove all biological activity from the soil. It could be a first step in using a truly green approach to turn the tide against pollution."

At first, the cresses would be used on sites that have only been "marginally polluted" and would be a cheap, visually pleasing way of reclaiming land for housing, parks or industry.

The current high costs of acid leaching or baking soil means that so far only prime sites such as those in the center of London have been worth cleaning. All that is set to change.

So effective are the cresses that, once cleaned, land could safely be returned to agricultural and horticultural use. Together with other techniques, the processes may even be used to decontaminate more severely polluted sites.

Though one of the species of cress involved is native to Britain, Baker refuses to name it or say where it grows. His concern is that an already rare plant could become a target for collectors.

In other countries, hyper-accumulator species are under threat as rain forests are cleared. Baker believes there's an urgent need to collect the plants and cultivate them for their own protection. Once over that hurdle, large-scale use for soil cleansing can start.

The technology may have other applications. One could be as a way to recycle metals lost as industrial or other waste. When the cresses are harvested and incinerated, the ash contains up to 20 percent metal oxides from which it is easy to remove the metals.

Though this is unlikely to be commercially viable yet, it may well become so as reserves are depleted and genetic engineering increases plants' ability to absorb the metals.

McGrath has high hopes for finding more hyper-accumulators, noting that there are already 243 known nickel accumulators and a lead accumulator is being studied. And Baker believes it's possible that accumulators may be found for precious metals.

27.8.93

Pflanzen ziehen Zink und Blei aus verseuchten Böden

dpa/ok **London** – Metallfressende Pflanzen gedeihen auf einem Feld des Instituts für Ackerbau und Getreidekunde in Rothamsted bei London. „Hyperakkumulatoren" hat sie der Biologieprofessor Steve McGrath wegen ihrer metallspeichernden Eigenschaften getauft: Hunderte von Sorten, darunter das Alpine Pfennigkraut und verschiedene Kohlarten. In Prozenten ihres Eigengewichtes, so McGrath, ziehen sie Schwermetalle aus dem Boden und speichern sie zum größten Teil in ihren Blättern. Er hofft, daß sich nach der Ernte aus der Pflanzenasche, die zu 20 Prozent aus Metalloxiden besteht, Metalle wiedergewinnen lassen.

Erste Versuchsergebnisse stimmen ihn „sehr, sehr optimistisch". Schon nach zehn Ernten habe sich der Anteil an Schwermetallen in einer Industriebrache auf landwirtschaftlich akzeptable Werte gesenkt. Der Boden war mit Kupfer, Cadmium, Nickel, Chrom und Blei verseucht gewesen. Eine besondere Vorliebe haben die Pflanzen für Cadmium und Zink entwickelt. „Zink kann ich ihnen auf unserem Boden aber leider nicht anbieten", bedauert McGrath.

Welcher biologischen Eigenart die „Hyperakkumulatoren" ihren Hunger auf Metall verdanken, wissen die Forscher noch nicht. Daß sie es tun, ist aber als botanische Kuriosität seit langem bekannt. Metallophythen heißen diese Pflanzen. Sie wachsen meist auf Schutthalden von Bergwerken. Zum Beispiel das Voralpen-Hellerkraut (Thlaspi alpestre). Es bevorzugt zinkreiche Standorte. Mit 100 Milligramm Zink pro Liter gedeiht es normal, mit 500 blüht es. Andere Pflanzen können bei diesem Zinkgehalt nicht gedeihen, so muß das Kraut keine Konkurrenz fürchten. Möglicherweise dient das aufgenommene Metall auch dem Selbstschutz, indem es Tieren den Appetit verdirbt.

Erst einmal konventionell, durch Auslese und Zucht, will McGrath die metallfressenden Talente seiner „Hyperakkumulatoren" verbessern. Sollten die Forscher sie mit Mitteln der Gentechnologie optimieren – wozu auch in England ein Genehmigungsverfahren nötig ist –, dann müßte sichergestellt werden, daß sich die metallfressenden Pflanzen nicht unkontrolliert vermehren. Eine Samenmischung gegen Schwermetalle müßte sich in ihrem Appetit auf metallische Böden beschränken.

INTERNATIONAL PRESS-CUTTING BUREAU
224-236 Walworth Road,
London SE17 1JE
Extract from
The Times, London
31 AUG 1993

British Association: new techniques offer hope for ecologists but problems for the health service

Rare plants swallow metals that poison the soil

BY NICK NUTTALL,
ENVIRONMENT
CORRESPONDENT

RARE plants from remote Pacific islands and alpine regions could be used to transform heavily polluted land.

British and New Zealand scientists have discovered a range of flowers, shrubs and trees which can concentrate metals such as zinc, chromium and lead in their leaves and stems.

Rather than being poisoned, the plants appear to thrive on soils polluted by heavy metals.

Professor Steve McGrath, of the Institute of Arable Crops Research at the Rothamsted experimental station in Harpenden, Hertfordshire, said yesterday: "Decontamination of soils polluted with heavy metals remains one of the most intractable problems of clean-up technology."

Rival techniques, ranging from chemical extraction of heavy metals from soils to immobilising affected areas by turning them to glass, all have drawbacks. These include cost and the need for special equipment and trained staff.

The plants promise a low-cost solution which, if successful, will be able to return polluted land back to agricultural, recreational or building use.

Some of the plants identified could also be harnessed for economic uses. One of the species, *Sebertia acuminata*, from New Caledonia in the Pacific, produces sap which is laden with nickel and chromium. It could be tapped for nickel for industrial uses in the same way as latex is tapped from trees to produce rubber, Professor McGrath said.

He said that smelting and metals companies were showing interest in their research. When burnt, the ash of the plants could contain as much as 20 per cent of heavy metals or the equivalent of a good ore. The chemical company Dupont had also expressed an interest in the plant as a way of cleaning lead-contaminated soil at an American factory that once produced the petrol anti-knock agent tetra-ethyl lead. The research, carried out in co-operation with Massey University in New Zealand, was funded by the European Community, the Leverhulme Trust and the United States army.

Biologists have found 69 families of plants capable of concentrating a wide range of heavy metals. Tests on about ten of the plants were recently completed in the London area to see if they would thrive in temperate British climes. The species used included the alpine penny-cress and alyssum, a flowering plant found in the mountain regions of Greece and Italy.

They were compared with oil-seed rape and radish in trials on land polluted by zinc-contaminated sewage sludge spread over it for 20 years. All of the new species outperformed the more common crops.

One of the exotic species extracted 43 kilograms of zinc a hectare from the soil, compared with 0.5 kilograms a hectare for oil-seed rape and 0.2 kilograms for radish.

The tests suggest that some of the plants could restore the land to safe levels of heavy metals within a decade. Planting oil-seed rape and radishes to clean up the soil would take between 800 and several thousand years.

Professor McGrath, speaking at the British Association's annual meeting, said that additional research was urgently needed to collect and conserve the rare plants used in the experiments. In some cases they were threatened by activities such as mining in their native habitats.

Cultivation programmes were also needed so that the promising plants could be brought into large-scale production for treating polluted land. More trials were needed to identify those that would grow fastest in countries such as Britain.

Professor McGrath said genetic studies to discover the genes that control the uptake of heavy metals in the plants were also required. Once identified, these could be engineered into other, possibly faster-growing native species such as willow or grasses.

Research was also needed to decide on the best way of disposing of the plants once they had become saturated with the heavy metals. Given the high concentrations of heavy metals which they absorbed it might be possible to extract and recycle them for industrial purposes, Professor McGrath suggested.

Dr Susan Gregson of the Applied Environmental Research Centre in Colchester, Essex, said the area of derelict land, including land contaminated by chemicals and heavy metals, could exceed 50,000 hectares in Britain.

Professor McGrath said there were vast areas of the country polluted with heavy metals. Many were near old mines or smelters. Most cities had a "halo" of heavy metals in soil around them, a legacy of past industrial activity. "Garden soils in old houses are quite contaminated."

BARRY GREENWOOD

Financial Times Tuesday August 31, 1993

Clean-up crops tested for work on toxic soils

PLANTS which take up toxic metals as nutrients could be used to clean contaminated soils. The crop would then be harvested and metal extracted for recycling.

Professor Steven McGrath of the Agricultural and Food Research Council's Institute of Arable Crops Research described the experimental process – called green remediation – to the British Association meeting.

His research team has tested a number of plants for zinc uptake on soils polluted by heavy metals from London sewage over 20 years.

The most efficient plant, alpine pennycress, reduced zinc to acceptable levels after nine croppings. Prof McGrath said this could be achieved in three years, using intensive cultivation.

Existing methods of physical and chemical treatment to remove soil pollution are expensive and also alter the soil structure, leaving it unsuitable for cultivation.

Using green remediation techniques, a hectare of contaminated soil could be cleaned up for £5,000, leaving it fertile, whereas conventional treatment by vitrification costs £18,000 per hectare.

At present the potential of the technique is limited by the productivity of the plants. Prof McGrath suggests that plants could be genetically engineered to speed up the rate of remediation and to improve the plants' take-up of toxic metals to levels where the metals could be harvested economically.

Du Pont, the international chemical company, is interested in using the technique to clean up lead contamination around factories where the petrol additive tetra ethyl lead was produced, and a smelting company plans a test to produce pure metals from harvested material.

Plants which have the ability to handle toxic metals are scarce and need to be protected, Prof McGrath said.

One of the champion natural accumulators is Sebertia acuminata, a tree that lives on nickel-rich soils. "An obvious application would be to 'tap' such trees for nickel, in an analogous way to that for rubber." Prof McGrath said green remediation could be combined with bioremediation, the technique in which bacteria are used to break down organic pollutants such as pesticidesto produce a one-stage clean-up.

He said he would also like to study plants in areas where there is a high level of radioactivity, to see if they accumulated radioactive materials.

The Guardian, Tuesday August 31, 1993

Cabbage 'king' in tackling poisons

Tim Radford

SCIENCE is on the verge of developing plants which can gulp up prodigious quantities of poisonous metals from contaminated land, then be recycled as though they were aluminium cans.

Metallic poisoning of soil — usually from mine workings, factory chimneys and effluent — has been a growing problem, particularly in eastern Europe.

Even the urban vegetable patch is not immune, Professor Stephen McGrath told the association's meeting.

But a range of weeds and crops has been found which flourishes on nickel, cobalt, zinc, cadmium and lead.

Professor McGrath, of the Rothamsted Experimental Station, said that within five years a plant could be grown especially for sowing on slag heaps and contaminated land.

"The ideal would be to harvest the plant material, dry it, and take it to smelters and recycle the metals in it, just as aluminium cans are recycled now." So far, out of 250,000 flowering plants, scientists have discovered nearly 100 which seem to have an appetite for toxic metals.

Professor McGrath and colleagues have been growing test plants on a field which has been contaminated by metals concentrated in London sewage sludge.

They made trials with plants they dubbed "hyperaccumulators."

One, a member of the cabbage family known as Thlaspi, or alpine pennycress, emerged as the star. A crop removed 43 kilograms of zinc per hectare in a mere nine harvests.

"It would do a very good job on zinc, but what we would like to know is, can it do other metals?" he said.

The plant could be genetically engineered to take up a cocktail of metals. But at present Professor McGrath is using more old-fashioned selection techniques to seek a superplant within the Thlaspi family which would perform even better, especially if encouraged by manure.

The Independent, Tuesday August 31, 1993

Plants suck metal from polluted land

PLANTS that "suck" valuable metals out of polluted soil could provide a lucrative crop for the future, scientists said yesterday.

Lead in land around Britain's abandoned smelting mines, or sprinkled for years on roadside verges, could be siphoned up, leaving clean, fertile soil.

Steven McGrath, from the Agricultural and Food Research Council's Institute for Arable Crops Research in Hertfordshire, told the meeting that such "hyper-accumulators" can store thousands of times more metal than "normal" species. The latex in one example, *Sebertia acuminata*, a native of metal-rich soils, can be 11 per cent nickel. It might be possible to tap these trees for nickel as others are tapped for rubber.

Scraping one metre of topsoil off a polluted site produces around 3,000 tons of metal-contaminated soil per hectare. This dries down to just a few kilograms of ash with metal concentrations of up to 20 per cent.

"We are told by people who do smelting that this is equivalent to a good ore," Dr McGrath said. He said Dupont, the United States chemical giant, is interested in using his "bio-ore" techniques to clean up land contaminated with lead.

"Around Britain's cities, metal industries have produced haloes of land polluted with metal deposits. The old mining sites where they smelted the lead emitted a lot of metal which came down on hills and moors," Dr McGrath said.

Dr McGrath's team tested 10 plant species on a site contaminated with 20 years' worth of London sludge and recorded the take-up of metals such as zinc, copper, manganese and cadmium. The researchers found that three species — a close relative of alyssum, an alpine penny cress and northern rock cress — had an unusually large capacity for storing metals.

He is confident that the work, funded in part by the US Army, should produce a cheaper way to deal with polluted land than any of today's approaches.

SUSAN WATTS
Science Correspondent

r scrutiny

"What are the insurance companies going to do [if] you have a gene that means you aren't going to see your mortgage expectancy through?"

Professor Evans said there was an urgent need for a debate on the ethical and social consequences of an increased lifespan. "It is timely to think about it so that we don't get taken by surprise if scientific dreams become reality."

Daliy Telegraph, 4th October 1993

It's cleaner by cabbage

2944

PLANTS from the cabbage family could clean land contaminated with toxic wastes, says Prof Stephen McGrath of the Rothamsted Experimental Station, Harpenden.

The plants have proved promising at removing zinc, cadmium and nickel. Trials have been funded by the EC, Leverhulme Trust and the US army to decontaminate a field treated with metal-contaminated sludge. The method could take another five years to develop. RH

Landmarks

Plants could clean contaminated land

Land contaminated with heavy metals could be cleaned by plants which extract the contaminants and store them in their above ground portions, according to a paper presented at the British Association for the Advancement of Science conference in August.

Steven McGrath, from the AFRC Institute of Arable Crops Research at Harpenden, said a number of plants acted as 'hyper accumulators', with leaves containing high concentrations of metals such as cadmium, copper, lead, nickel and zinc.

Plants growing on a contaminated site could be cropped, and the metal-enriched biomass either disposed as landfill or reduced to ash, which could allow metals to be recovered and recycled.

Professor McGrath said the 'green remediation' of contaminated sites would leave soil in better condition than other clean-up techniques, such as acid-leaching, electro-osmosis, or vitrification, which remove all biological activity and affect the soil structure.

Species of plants which act as hyper accumulators vary from herbaceous plants to trees. The latex of one tree, *Sebertia acuminata* from New Caledonia, contains more than 11 per cent nickel, which could possibly be 'tapped', as other trees are for rubber.

An experiment was carried out on a field where metal-contaminated sludge from London had been applied for 20 years. Ten species were grown to test their ability to remove metals, one of which, *Thlaspi caerulescens*, reduced the amount of zinc in the soil to an acceptable level after just nine croppings. *Alyssum lenium* would remove the same amount of zinc after 88 croppings, and oilseed rape, by contrast, would require 832 croppings.

Professor McGrath pointed out that hyper accumulator plants are relatively rare, and often grow in remote areas. Some of the plants are hard to crop, and new machinery may have to be developed to cope with low-growing or short-lived species.

'We look forward to seeing contaminated and abandoned sites 'growing clean' with a cover of yellow and white flowers of hyper accumulator plants'.

More research needs to be done to identify other suitable species, and to find ways of increasing their efficiency as accumulators, he added.

Copies of *Plants clean up soils* can be obtained from Professor Steven McGrath, Soil Science Department, Rothamsted Experimental Station, Harpenden, Hertfordshire AL5 2JQ.

● Botanists at Cambridge University are breeding a variety of elm which has greater resistance to Dutch elm disease than the ordinary elm, and which could be used to replant areas devoid of the tree for more than 20 years. About 200 saplings of the smooth-leaved elm are being planted around Cambridgeshire as a pilot study.

MARTIN GREAMER'S ENGINEERING News EVERY FRIDAY

Plants may be able to save poisoned soils

SCIENTISTS believe that plants may solve the problem of decontaminating polluted soils following their discovery that a small but growing number are capable of accumulating very high concentrations of metals in their stems and leaves.

More than 70 species are now known to be what are classified as hyperaccumulators.

These contain hundred to thousands times larger metal concentrations in their above ground parts than normal, and range from herbaceous flowering plants to trees.

"The discovery of an increasing number of hyperaccumulator plants has opened up the prospect of seeing contaminated and abandoned sites 'growing green' with a cover of yellow and white flowers of hyperaccumulator plants," says **Dr Steven McGraph** from Britains Institute of Arable Crops Research at Harpenden, near London.

At present there are no such techniques for such a clean up which are low cost and retain soil fertility after the metals contamination has been removed.

Hyperaccumulator plants include Sebertia acuminata, which is native to nickle/chromium-rich soils in New Caledonia. The latex in this tree contains more than 11% nickel and is blue because of this.

"An obvious application would be to tap such trees for nickel in an analogous way to that for rubber," he says.

Backed financially by the European Community and the Leverhume Trust scientists in Britain and New Zeaiand have been carrying out field experiments on a site where metal-contaminated sludge from London had been spread for 20 years.

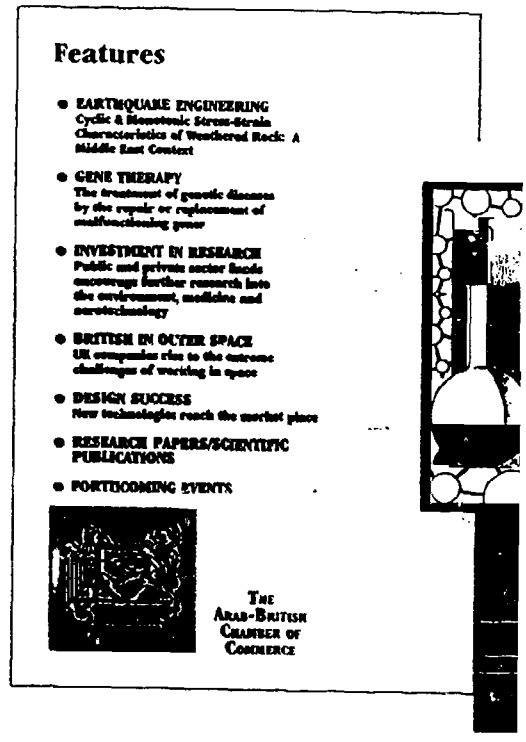
Ten species of plant were grown to test their efficiency for removing metals in above ground biomass.

"This method shows promise for cleaning a modestly polluted site, in situations where the remediation can be considered over a number of years.Mixtures of species might be grown in future rather than the monocultures used in our tests, in order to remove several metals simultaneously where there is the usual multiple contamination," continues McGraph.

Because hyperaccumulator plants are still relatively rare and found only in remote areas, there was an urgent need to collect and cultivate them, and to establish a germplasm facility for their large scale production.

Future work could involve genetic engineering to further improve metal uptake characteristics once the genes for metal accumulation had been identified.

The possibility then existed to transfer genes for metal hyperaccumulation into a productive but inedible host plant.



PLANTS CAN CLEAN UP CONTAMINATED SOILS
نباتات تنظف التربة الملوثة

يعتقد علماء النبات أن بعض الفصائل النباتية يمكنها أن تحل مشكلة تنظيف التربة الملوثة وذلك عقب اكتشافهم أن هناك عدد صغير، ولكن آخذ في الازدياد، من النباتات التي يمكنها تخزين وتركيم تجمعات كبيرة من المعادن في جذوعها وأوراقها.

Scientists believe that plants may solve the problem of decontaminating polluted soils following their discovery that a small but growing number are capable of accumulating very high concentrations of metals in their stems and leaves, and more than 70 species are now known to be what are classified as hyperaccumulators.

At present there are no techniques for such a clean-up which is low cost and retains soil fertility after the metals contamination has been removed. Hyperaccumulator plants are still relatively rare, and found only in remote areas an urgent need to collect ar them, and to establish a facility for their large-scale pr

For further information, please Stephen McGraph, AFRC Arable Crops, Rothamsted E Station, Harpenden, Herts AI 44-582 763133; Fax: 44-582 7

Independent on Sunday 13/3/94.

Trees that can draw out the poison

Planting may prove to be the best way of cleaning up polluted land. Nuala Moran reports

COMPANIES responsible for restoring polluted industrial sites may be able to cut clean-up costs by planting trees that absorb poisonous heavy metals. They could then gain commercially by harvesting the wood that shoots from the roots of the trees after they have been cut down.

This approach, known as green remediation, is suggested by scientists at Glasgow University, who are beginning the search for suitable trees by analysing this year's growth of alders, willows and poplars on a site that has been poisoned by decades of heavy industrial use.

The decontamination of soils polluted with heavy metals is one of the most difficult problems in cleaning up derelict land. Existing techniques of chemical and physical extraction or immobilisation in situ, are all expensive and require special equipment and operators. Vitrification, for example, costs about £18,000 for each hectare (2.5 acres). These methods also remove all biological activity from the soil and damage its physical structure.

With funding from Scottish Enterprise, Dr Ian Pulford and his colleagues in Glasgow will also grow trees in soils contaminated with controlled amounts of cadmium, chromium and zinc to measure absorption rates and calculate the time it would take to clean up a given volume of soil. The scientists need to establish where the metals are distributed in the tree. If they end up in the leaves, the scheme would be pointless, because the soil would be recontaminated each autumn.

The Government is currently offering farmers grants in an attempt to revive coppicing – the practice of cutting trees down to root level and then harvesting the wood that shoots from the base – as a fuel for power stations, and cash could also be earnt in this way.

Planting and tending a woodland until it can be coppiced costs about £1,300 a hectare, but as the market is not yet established, it is unclear how much coppiced wood would be worth. Wood from contaminated sites could not be used for fuel, since this would spread the pollution.

Many industrial sites are in built-up areas and Dr Pulford says planting trees that can extract heavy metals will also have the advantage of providing cover to prevent the pollution spreading in water run-off or blowing around in dust.

Another research group, led by Dr Steven McGrath at the government's Arable Crops Research Station at Rothamsted, Hertfordshire, is studying the use of plants that grow in naturally metal-rich soils for remediation. Dr McGrath says some plants accumulate metals at such high levels that they could provide a source of those metals. Genetic engineering to improve the uptake of metal is also on the agenda.

If these methods of green remediation can be proven, Dr Pulford suggests that metal-accumulating plants and trees could be used in combination with bioremediation, in which micro-organisms are added to soil to break down organic pollutants, to clean up polluted sites completely.

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Pflanzen zur Entgiftung kontaminierter Böden

(BN) Nachdem Wissenschaftler entdeckt haben, dass einige Pflanzenarten in der Lage sind, sehr hohe Konzentrationen von Metallen in ihren Stielen und Blättern zu speichern, haben sie die Ansicht geäussert, dass Pflanzen vielleicht zur Lösung des Problems kontaminierter Böden beitragen könnten.
Über 70 Arten sind bisher bekannt und werden als sogenannte «Hyperakkumulatoren» bezeichnet. Die Pflanzen, unter denen krautartige bis hin zu Bäumen vertreten sind, enthalten das 100- bis 1000fache der üblichen Metallkonzentration in ihren oberirdischen Sprossen.

Dr. Steven McGraph vom *Institute of Arable Crops Research* in Harpenden bei London sagte kürzlich auf einer Konferenz, dass die Entdeckung von immer mehr Hyperakkumulatoren die Perspektive eröffnet habe, kontaminierte Böden und Industriebrachen mit einem Teppich weiss- und gelbblühender Hyperakkumulator-Pflanzen zu reinigen. Gegenwärtig gibt es kein Reinigungsverfahren, das kostengünstig ist und die Bodenfertilität nach Beseitigung der Metallbelastung erhält.

Als ein Beispiel eines solchen Hyperakkumulators nannte Dr. McGraph die *Sebertia acuminata*, die auf nickel- und chromreichen Böden in Neukaledonien heimisch ist. Der Latex dieses Baumes enthält über 11% Nickel und ist daher bläulich gefärbt. Laut Dr. McGraph wäre es nur logisch, solche Bäume analog zur Gummigewinnung zur Gewinnung von Nickel anzuzapfen.

Mit finanzieller Unterstützung der Europäischen Union, des Leverhume Trust und der US-Armee haben Wissenschaftler aus Grossbritannien und Neuseeland Feldversuche auf einem Boden durchgeführt, auf den 20 Jahre lang schwermetallbelasteter Schlamm aufgetragen worden war. Darauf wurden zehn Pflanzenarten ausgepflanzt und auf ihre Fähigkeit untersucht, Schwermetalle aufzunehmen.

Dr. McGraph sagte zu den Ergebnissen: «Diese Methode zeigt vielversprechende Ansätze zur Reinigung einer mässig belasteten Industriebrache, wenn man für die Reinigung einige Jahre Zeit hat. In Zukunft kann man vielleicht eine Mischung verschiedener Arten auspflanzen, statt der in unseren Versuchen gepflanzten Monokulturen, um dem Boden dort, wo es sich um die übliche Mehrfachverschmutzung handelt, mehrere Metalle gleichzeitig zu entziehen.»

Da Hyperakkumulatoren noch verhältnismässig unbekannt sind und bisher nur in abgelegenen Gebieten gefunden wurden, sieht Dr. McGraph die Notwendigkeit, sie zunächst zu identifizieren und zu kultivieren und eine Keimplasma-Einrichtung für ihre Zucht zu gründen. In der Zukunft könne man versuchen, die metallspeichernden Eigenschaften mit Hilfe der Gentechnik zu optimieren, wenn die für die Metallansammlung zuständigen Gene identifiziert seien. Dann bestehe die Möglichkeit, die entsprechenden Gene auf leistungsfähige, aber ungeniessbare Wirtspflanzen zu übertragen.

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Extract from
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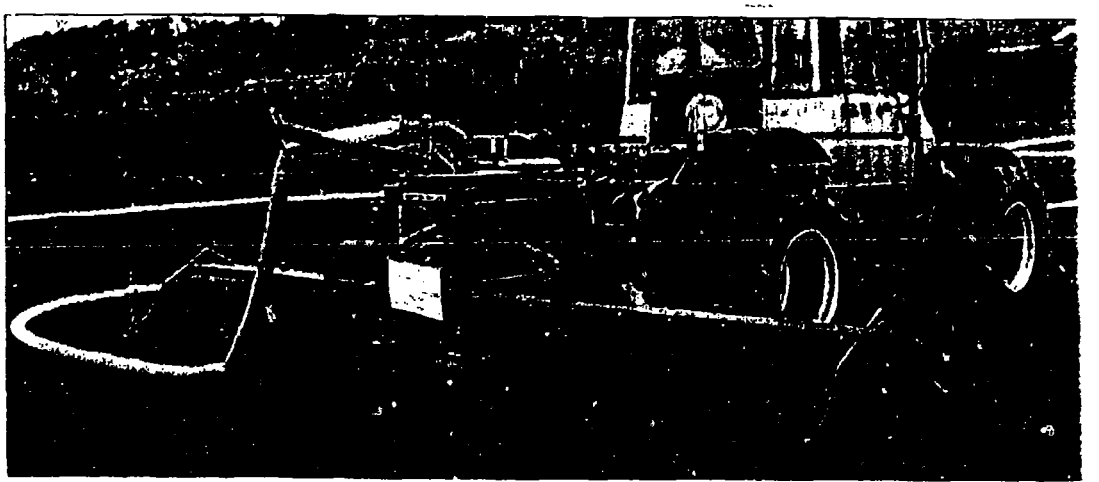
25/3/94

ARIA MEETING

Sewage sludge cleansed

Maintaining soil quality gave delegates at last week's meeting of the Arable Research Institute Association plenty to talk about. **Andrew Blake** reports



Any heavy metal build-up following sewage sludge application could be rectified using "hyper-accumulator" plants which concentrate the metals in their tissues. Offtake may be 300 times higher than normal cropping.

FARMERS on land polluted by heavy metals, perhaps from sewage sludge, could eventually be able to clean it up by growing special crops.

According to Professor Steve McGrath of Rothamsted Experimental Station, it might even be possible to recover valuable metals by processing the harvested plants.

He points out that the amount of sewage sludge destined to end up on farms after 1998, when it may no longer be dumped at sea legally, is likely to double.

Control of industrial effluents has helped reduce the amount of heavy metals like zinc, cadmium and lead in sludges. But much comes from domestic sources. Increased recycling of municipal wastes and the use of composts is likely to add to the burden.

Unlike nitrogen, such metals leach only very slowly, says Prof McGrath. Field tests in 1985 showed that more than 80% of the zinc, cadmium, copper, nickel, chromium and lead applied between 1942 and 1961 remains in the cultivated layer. "They are very persistent and stay in the topsoil." Normal cropping might take 2000 years to remove them.

Long-term trials have proved they could harm nitrogen-fixing bacteria associated with white clover, he explains. The possibility that other soil micro-organisms could similarly be affected merits a cautious approach.

A recent government review on the use of sewage sludge recommended that the legal limits be tightened. The justification for setting different levels according to soil pH is also due for a rethink.

A more radical way forward is the use of so-called "hyper-accumulators". These are plants which are unusually efficient at concentrating heavy metals in their tops.

In what Prof McGrath believes is the world's first field experiment to test the idea, researchers at Woburn have discovered some species could absorb up to 30,000 parts per million of zinc but stay healthy. "A normal plant on healthy soil would have about 30ppm, and on polluted soil 300ppm."

Kontaminierte Böden mit Pflanzen entgiften

Verschiedene Pflanzenarten lassen sich zur Dekontamination von Böden einsetzen, die mit Metallen belastet sind. Englische Wissenschaftler fanden heraus, daß bestimmte Pflanzen in der Lage sind, sehr hohe Konzentrationen von Metallen in ihren Stielen und Blättern zu speichern. Über 70 Arten mit entsprechenden Eigenschaften sind bisher bekannt und werden als sogenannte „Hyperakkumulatoren" bezeichnet. Die Pflanzen, unter denen krautartige bis hin zu Bäumen vertreten sind, enthalten das 100- bis 1000-fache der üblichen Metallkonzentration in ihren oberirdischen Trieben.

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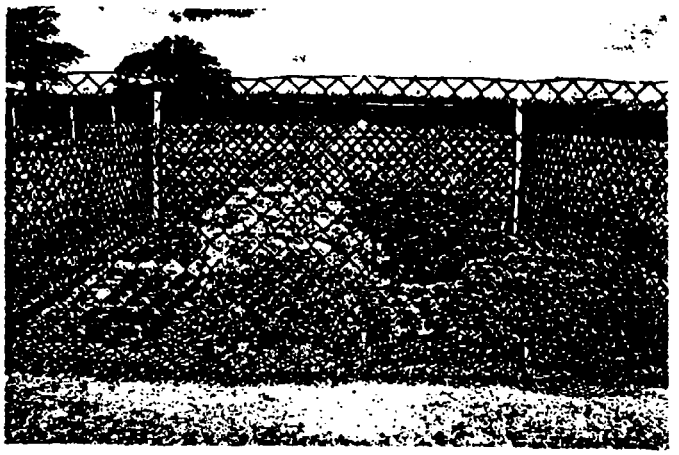
Der Wissenschaftler zu den Ergebnissen: „Diese Methode zeigt vielversprechende Ansätze zur Reinigung einer mäßig belasteten Industriebrache, wenn man für die Reinigung einige Jahre Zeit hat. In Zukunft kann man vielleicht eine Mischung verschiedener Arten auspflanzen statt der in unseren Versuchen gepflanzten Monokulturen, um dem Boden dort, wo es sich um die übliche Mehrfachverschmutzung handelt, mehrere Metalle gleichzeitig zu entziehen."



Acht verschiedene Arten Hyperakkumulatoren wurden versuchsweise auf kontaminierten Bodenparzellen angepflanzt.

Da Hyperakkumulatoren noch verhältnismäßig unbekannt sind und bisher nur in abgelegenen Gebieten gefunden wurden, sieht der englische Wissenschaftler die Notwendigkeit, sie zunächst zu identifizieren und zu kultivieren und eine Keimplasma-Einrichtung für ihre Zucht zu gründen. In der Zukunft könne man versuchen, die metallspeichernden Eigenschaften mit Hilfe der Gentechnik zu optimieren, wenn die für die Metallansammlung zuständigen Gene identifiziert seien. Dann bestehe die Möglichkeit, die entsprechenden Gene auf leistungsfähige, aber ungenießbare Wirtspflanzen zu übertragen.

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